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Availability and Use of Medical Isotopes in Canada

Performed as part of a Radiological Terrorism Risk Assessment

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Abstract

An assessment of the availability of radioactive material used for medical applications in Canada has been performed as part of the CBRN Research and Technology Initiative (CRTI) Project CRTI-02-0024RD (Probabilistic Risk Assessment Tool for Radiological Dispersal Devices). A general list of medical radioisotopes used worldwide was compiled via literature searches and Internet investigations. This list was then compared to all isotopes licenced to healthcare facilities in Canada. Sources of lesser concern for this study, such as noble gases, short-lived isotopes, and radioisotopes not licenced for medical applications in Canada, were eliminated. The remaining sources were then analysed for frequency of use and maximum licenced activity to assess which materials would be of highest concern in relation to radiological terrorism. A detailed description of the application, typical administered activity, and other relevant information for these most common and highest licenced activity medical sources was assembled to feed directly into the risk assessment database. A general discussion of security in healthcare facilities is also given. Due to the constant advances made in medicine, the information relating to licenced isotopes is dynamic and thus requires updating to ensure the database is kept current.

Résumé

Une évaluation de la disponibilité des matières radioactives utilisées dans des applications médicales au Canada a été effectuée dans le cadre du projet IRTC 02-0024RD (Outil destiné à une évaluation probabiliste de la sûreté des dispositifs de dispersion radiologique) de l'Initiative de recherche et de technologie CBRN (IRTC). Une liste générale de radioisotopes à usage médical utilisés dans le monde a été dressée au moyen de recherches dans la littérature et sur Internet. Cette liste a ensuite été comparée à celle de tous les isotopes dont l'utilisation est autorisée à des fins médicales dans les établissements de santé du Canada. Les sources moins préoccupantes pour cette étude (p. ex. gaz rares, isotopes de courte durée de vie et radioisotopes dont l'utilisation n'est pas autorisée à des fins médicales au Canada) ont été éliminées. Pour évaluer quelles matières seraient les plus préoccupantes en ce qui a trait au terrorisme radiologique, on a ensuite analysé les sources restantes pour en déterminer la fréquence d'utilisation et l'activité maximale autorisée. Pour les sources médicales le plus couramment utilisées et dont l'activité maximale autorisée est parmi les plus fortes, on a fait une description détaillée de l'application et des doses habituelles administrées et on a rassemblé d'autres renseignements pertinents afin d'intégrer directement toutes ces données dans la base de données pour l'évaluation du risque. Une analyse générale de la sécurité dans les établissements de santé est aussi présentée. En raison des percées constantes dans le domaine de la médecine, l'information concernant les isotopes autorisés est dynamique, et il faut donc l'actualiser pour s'assurer que la base de données demeure à jour.

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Executive summary

Introduction: Radioisotopes are used widely for a large variety of medical procedures in Canada. To assess the risk of these materials being used for illicit purposes, specifically in a radiological dispersal device (RDD), availability and security of these sources needs to be addressed. This was the purpose of the present study. This document summarises the information gathered from a variety of sources, identifying the highest activity and most frequently used medical isotopes in Canada, and comments on the security of this material in a healthcare setting.

Results: Approximately 140 radioisotopes are used worldwide in medical applications. The number of radionuclides licenced in Canada for medical purposes are about 60% of this. The highest activity (and thus highest risk) sources have more stringent security procedures in place to protect them, however smaller activity sources with less severe security requirements may still pose a threat since multiple sources may be combined together into a single device. Lists of the highest licenced activity and most frequently licenced medical radioisotopes in Canada were compiled from a Canadian Nuclear Safety Commission (CNSC) database of small and medium licencees. These lists were then compared to an IAEA list of sources categorized based on their risk to human health. Many isotopes appear on all three of these lists, indicating the most prevalent medical isotopes in Canada.

Significance: This study identifies a wide variety of radioactive sources used in medical procedures for inclusion in a probabilistic risk assessment database. Information on the frequency of use and maximum licenced activity of these isotopes will be used to influence the probability assessment output from the PRA tool for a selected medical isotope. This information is representative of the radioactive licences in Canada in early 2004, and thus should be updated periodically to ensure the information remains current.

Larsson CL. 2004. Availability and Use of Medical Isotopes in Canada – Performed as part of a Radiological Terrorism Risk Assessment. DRDC Ottawa TM 2004-218. Defence R&D Canada - Ottawa.

Sommaire

Introduction : Les radioisotopes sont abondamment utilisés dans diverses procédures médicales au Canada. Pour évaluer le risque d'utilisation de ces matières à des fins illicites, plus précisément dans des dispositifs de dispersion radiologique (DDR), il faut déterminer la disponibilité et la sûreté des sources de radioisotopes. C'était là le but de l'étude. Le présent document résume l'information recueillie à partir de diverses sources. Il identifie les isotopes dont l'activité maximale est parmi les plus fortes et qui sont le plus souvent utilisés à des fins médicales au Canada. Il renferme aussi des commentaires concernant la sûreté de ces matières dans les établissements de santé.

Résultats : Quelque 140 radioisotopes sont utilisés dans le monde à des fins médicales. Le nombre de radionucléides autorisés au Canada pour un usage médical équivaut environ à 60 % du total mondial. Les sources dont l'activité est parmi les plus fortes (et qui posent donc le plus grand risque) sont soumises à des règles de sécurité plus rigoureuses afin de les protéger, bien que les sources de plus faible activité, et donc soumises à des règles de sécurité moins sévères, pourraient tout de même constituer un danger, étant donné que plusieurs sources pourraient être combinées dans un seul dispositif. La liste des radioisotopes autorisés dont l'activité maximale est parmi les plus fortes et la liste des radioisotopes le plus fréquemment autorisés pour un usage médical au Canada ont été compilées à partir de la base de données de la Commission canadienne de sûreté nucléaire (CCSN) concernant les établissements de taille petite et moyenne titulaires de licences. Ces listes ont ensuite été comparées à une liste de sources de l'Agence internationale de l'énergie atomique (AIEA) classées selon le risque qu'elles entraînent pour la santé humaine. De nombreux isotopes figurent sur les trois listes; ils constituent les isotopes le plus fréquemment utilisés à des fins médicales au Canada.

Portée : L'étude recense une grande variété de sources radioactives utilisées à des fins médicales qui pourraient être incluses dans une base de données pour l'évaluation probabiliste du risque. Les renseignements concernant la fréquence d'utilisation et l'activité maximale autorisée de ces isotopes seront utilisés pour l'évaluation des probabilités au moyen de l'outil d'évaluation probabiliste du risque pour un isotope d'usage médical choisi. Ces renseignements sont représentatifs des licences d'utilisation de matières radioactives en vigueur au Canada au début de 2004 et devraient donc être actualisés régulièrement pour demeurer à jour.

Larsson C. L. 2004. Availability and Use of Medical Isotopes in Canada – Performed as part of a Radiological Terrorism Risk Assessment. DRDC Ottawa TM 2004-218. R & D pour la défense Canada - Ottawa.

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1. Introduction

Radioactive materials are employed in thousands of commercial applications in medical, academic, and industrial settings worldwide. Recently, the safety and security of these sources has been under scrutiny due to the perceived increased threat of the acquisition/manufacture and use of a radiological dispersal device (RDD) by terrorist organizations. Use of low-grade or non-fissile material for this purpose is regarded as highly likely due to the low level of security surrounding such sources [1]. To accentuate the importance of these materials in relation to radiological terrorism, the International Atomic Energy Agency (IAEA) has reported that the illicit trafficking of non-fissile materials exceeds that of fissile materials by almost an order of magnitude [2].

A CBRN Research and Technology Initiative (CRTI) Project entitled "Probabilistic Risk Assessment Tool for Radiological Dispersal Devices" (CRTI-02-0024RD) was awarded in April 2003. The goal of this project is to develop a comprehensive probabilistic risk assessment (PRA) for RDDs that will address all aspects of RDD construction and use, including materials acquisition, device construction, delivery mechanisms, and consequence assessment [3]. In order to properly assess the threat of RDD deployment within Canada, a thorough investigation of source availability must be performed. Some of the key properties that help to identify the degree of security risk include energy and type of radiation; half-life of the radioisotope; amount of material; shape, size, shielding, and portability of the source; prevalence of use; and dispersibility of the source material [4]. In the process of addressing these points for the CRTI "PRA Tool for RDDs" project an assessment of the availability and security of radioactive sources used in medical applications was performed.

Nuclear applications have become commonplace and cost effective in the Canadian health care system, contributing significantly to the prevention, diagnosis and cure of many ailments. Furthermore, Canada is a world leader in the production of radioisotopes used in medicine and in other applications. Both of these facts suggest the presence of a large number of medically used radiological sources in Canadian hospitals and in transit to other countries. This study investigates the use and availability of medical radioisotopes in Canada, discusses the security of these sources in a hospital setting and in transit, and attempts to make risk categorizations of radionuclides used in the healthcare setting.

2. Source Security

Radiological and nuclear applications in medicine have become increasingly frequent, with billions of procedures performed worldwide per year [5]. While not all of these applications employ radioactive sources (X-ray imaging, teletherapy with a linear accelerator), a significant number do and the variety of radionuclides, forms, and quantities of material used is large. Thus, in order to adequately perform a risk assessment on the likelihood of RDD deployment, an assessment of the security of these sources within a hospital setting is required.

Following production, radiological pharmaceuticals are handled several times before reaching a medical facility [6]. In situations where the radioisotope processing facility is not the same as the pharmaceutical distributor's location, transportation between these locations is necessary. The radionuclides must be transported from distributor to the hospital and this is usually done via air and/or road transport. The short half-life of many radiopharmaceuticals used in medicine requires speedy delivery, and thus air transport is often necessary. The isotopes are then received at the hospital's shipping and receiving, the appropriate person is contacted, and the material is transported to a secure storage location (preferably on a cart in a shielded container to reduce unnecessary dose to the transporter).

There are several departments within a hospital that might utilize radioactive sources, the most common being nuclear medicine departments, cancer centres, laboratory services, and research laboratories. The security surrounding the sources in each of these different departments varies, although this variation is mainly related to source hazard. Every healthcare facility that is licenced to possess radioactive sources will have a radiation safety program in place ensuring that the policies and procedures surrounding the use of radioactive material comply with regulatory requirements.

The nuclear medicine department uses large quantities of radiopharmaceuticals on a regular basis. The short half-life of many of these isotopes (required by their injection into patients) mandate their delivery on a monthly basis, if not more frequently. For instance, Molybdenum-99/technitium-99m generators, used in as many as 80% of all diagnostic nuclear medicine procedures, require weekly delivery due to ^{99}Mo's short half-life. Radioactive materials are usually kept in a radiopharmacy laboratory (or "hot lab"). The "hot lab" (the location where radiopharmaceuticals are prepared for administration to patients) is a locked area providing access only to authorized personnel. Radioactive material must be logged out upon removal from the lab, and records are available only to authorized personnel.

Therapeutic applications of radiation techniques are used frequently in the treatment of cancer [7]. Delivery of radiation can be performed externally, called teletherapy, or via the insertion of radioactive sources into cavities adjacent to a tumour or interstitially directly into a tumour, called brachytherapy. The sources used for these treatments are typically longer-lived sealed sources, although some shorter-lived isotopes are used for permanent implant sources. A third emerging treatment deals with the administration

of short-lived alpha or beta emitting radiopharmaceuticals designed to target tumours in a particular location of the body. A variety of sources are used for these purposes and their activity varies considerably depending on the application.

Many of the external radiotherapy procedures performed in Canadian cancer clinics now use radiation-generating devices, such as linear accelerators. However, there are approximately 207 ^{60}Co units in use in North American radiotherapy clinics due to their reliability and high efficacy in treating small superficial tumours. Typical activity is very large and the source is contained and shielded within the device. While the intense radiation sources used in this application yield significant potential for incidents with serious consequences [8], the security surrounding these sources within the hospital is stringent. Specifically, daily accounting of the source, access control to the source location, two technical measures separating the source from unauthorized personnel, remotely monitored intruder alarms, and a variety of response plans are recommended by international regulations [9].

Internal radiotherapy uses a wider variety of radioactive sources, which range from high, medium and low dose-rate and are typically more portable compared to those used in external radiotherapy. Security surrounding these sources is less stringent, ranging from weekly accounting, access control to the source location, a technical measure separating the source from unauthorized personnel, local alarms and a variety of response plans for higher activity sources to annual accounting with no specific safety provisions for the lowest activity sources. While the higher activity sources would be more devastating in an RDD, multiple smaller sources could be combined into a single device, and accessibility to such sources is less challenging.

Laboratory services and research laboratories within a hospital use an assortment of radioisotopes in the diagnosis of diseases from patient samples and in the development of new diagnostic techniques. Radioisotopes are typically in liquid form and are stored in easily portable containers. The overall activity of these sources is typically small and thus the security surrounding them is less stringent. Annual accounting along with the possibility of securing the sources in a locked cabinet is the extent of the recommended security applied to these isotopes.

3. Medical Isotopes in Canada

Almost 20 million nuclear medicine procedures and over 100 million laboratory tests using radioisotopes are performed worldwide each year. These procedures include diagnostic (both *in vivo* and *in vitro*), therapeutic, and preventative applications. Canada is one of the world's largest producers of radioactive materials, particularly for use in medical applications. In particular, MDS Nordion, headquartered in Ottawa, is the supplier of over half of the world's reactor-produced isotopes and a wide variety of cyclotron-produced isotopes.

A literature and Internet search performed to identify radioisotopes used in medicine resulted in a list of approximately 140 radioactive sources out of a list of over three thousand isotopes in existence, shown in Table 1. However, only ten of these isotopes are used in 90% of all *in vivo* nuclear medicine procedures performed per year [6]. As a testament to this, the radioisotope ^{99m}Tc is used in as many as 80% of all diagnostic imaging studies of various organs. Others are used in therapy and laboratory analysis.

Table 1. *Radioisotopes used in medical applications*

^{3}H	^{51}Mn	^{72}As	^{96}Tc	^{125}I	^{169}Er	^{195m}Au
^{7}Be	^{52}Mn	^{74}As	^{99m}Tc	^{131}I	^{169}Yb	^{198}Au
^{11}C	^{52m}Mn	^{72}Se	^{97}Ru	^{132}I	^{170}Tm	^{201}Tl
^{14}C	^{52}Fe	^{75}Se	^{103}Ru	^{127}Xe	^{171}Tm	^{203}Pb
^{13}N	^{55}Fe	^{75}Br	^{106}Ru	^{133}Xe	^{177}Lu	^{210}Pb
^{15}O	^{59}Fe	^{77}Br	^{99}Mo	^{130}Cs	^{178}Ta	^{212}Pb
^{18}F	^{55}Co	^{82}Br	^{103}Pd	^{131}Cs	^{179}Ta	^{210}Bi
^{22}Na	^{57}Co	^{81m}Kr	^{109}Pd	^{137}Cs	^{182}Ta	^{212}Bi
^{24}Na	^{58}Co	^{85}Kr	^{103m}Rh	^{137m}Ba	^{178}W	^{213}Bi
^{32}P	^{60}Co	^{81}Rb	^{105}Rh	^{139}Ce	^{186}Re	^{211}At
^{33}P	^{61}Cu	^{82}Rb	^{106}Rh	^{141}Ce	^{188}Re	^{222}Rn
^{35}S	^{62}Cu	^{82}Sr	^{109}Cd	^{145}Sm	^{188}W	^{223}Ra
^{42}K	^{64}Cu	^{85}Sr	^{109m}Ag	^{153}Sm	^{191m}Ir	^{226}Ra
^{43}K	^{67}Cu	^{89}Sr	^{111}In	^{149}Tb	^{192}Ir	^{225}Ac
^{44}Sc	^{62}Zn	^{90}Sr	^{113m}In	^{152}Eu	^{194}Ir	^{227}Ac
^{46}Sc	^{65}Zn	^{88}Y	^{115m}In	^{155}Eu	^{191}Os	^{228}Th
^{47}Sc	^{64}Ga	^{90}Y	^{117m}Sn	^{153}Gd	^{194}Os	^{229}Th
^{44}Ti	^{67}Ga	^{91}Y	^{122}I	^{159}Gd	^{195m}Hg	^{238}Pu
^{47}Ca	^{68}Ga	^{95}Zr	^{123}I	^{165}Dy	^{197}Hg	^{241}Am
^{51}Cr	^{68}Ge	^{95}Nb	^{124}I	^{166}Ho	^{203}Hg	^{252}Cf

Information on isotopes used in Canada was requested from the Canadian Nuclear Safety Commission (CNSC). As regulator, CNSC holds information on all licensees within Canada in terms of what radioactive materials they are allowed to possess and in what quantities, along with other information. A list of all small and medium users was provided from their database [10]. This list was then scoured to identify all isotopes licenced to healthcare-related facilities. It was assumed that sources licenced to these types of facilities would be stored at the same location as the licence location.

In Canada, a total of 86 isotopes (or groups of isotopes) were licenced to healthcare facilities and/or medical laboratories in early 2004 [10]. A list of these isotopes, the range of licenced activities, and the total number of healthcare-related licencees of that isotope are listed in Table 2. In the overview of medical radionuclides licenced in Canada, several instances of a particular isotope being reported in different ways were observed. For instance, both ^{99}Mo/^{99m}Tc, and ^{99m}Tc were licenced, despite the fact that these two classifications likely referred to the same application of the isotope (i.e. use of ^{99m}Tc from a ^{99}Mo/^{99m}Tc generator). In these instances, multiple entries have been reduced to a single isotope.

Perusal of the medical radioisotopes licenced in Canada gives an estimation of the prevalence of use of the various sources. The following section discusses isotopes licenced by many users and those licenced in relatively large quantities. A description of the application, typical administered activity, and other relevant information for the most common and highest licenced activity medical sources is given in Annex A.

Table 2. *List of licenced medical isotopes in Canada. Highlighted isotopes indicate noble gases and very short-lived isotopes*

ISOTOPE / SOURCE	LICENCED ACTIVITY (MBq)	NUMBER OF LICENCEES	ISOTOPE / SOURCE	LICENCED ACTIVITY (MBq)	NUMBER OF LICENCEES
^{3}H	40 – 3.7E+6	29	^{90}Sr/^{90}Y	2 – 3E+5	68
^{11}C	1E+3 – 4E+5	19	^{95}Nb	80 – 3E+2	2
^{13}N	1E+3 – 1.85 E+5	14	^{99}Mo/^{99m}Tc	50 – 5E+6	220
^{14}C	0.925 – 4E+4	44	^{103}Pd	74 – 8E+2	5
^{15}O	1E+3 – 4E+5	15	^{106}Ru	50	1
^{18}F	1E+2 – 4E+5	48	^{109}Cd	0.4 – 6E+3	3
^{22}Na	0.4 – 4E+3	25	^{109}Cd/Ag	40	1
^{24}Na	2.5E+2 – 1.11E+5	3	^{111}In	40 – 5E+4	171
^{32}P	40 – 7.44E+4	130	^{113}Sn/^{113m}In	4E+3 – 2E+5	8
^{33}P	33 – 4E+3	21	^{114}In	3E+2	1
^{35}S	10 – 2.5E+4	30	^{117m}Sn	4E+3 – 1E+4	4
^{42}K	2.5E+2 – 1.11E+5	4	^{123}I	20 – 5E+4	145
^{45}Ca	40 – 1E+3	17	^{124}I	2 – 1E+5	5
^{46}Sc	20 – 3E+2	4	^{125}I	0.4 – 1.2E+4	149
^{47}Ca	10 – 2E+2	3	^{129}I	2E-3 - 4	17
^{51}Cr	5 – 7E+3	123	^{131}I	1 – 8E+4	320
^{54}Mn	0.25 – 1E+2	5	^{127}Xe	7.75E+2 – 7.4E+4	19

^{55}Fe	0.15 – 1E+3	6	^{133}Xe	1E+3 – 1.5E+5	11
^{56}Mn	1.11E+5	1	^{133}Ba	4E-3 – 5.92E+2	123
^{57}Co	0.15 – 9E+3	348	^{137}Cs	4E-2 – 4.4E+8	326
^{58}Co	0.2 – 3E+3	86	^{137}Cs/^{137m}Ba	40 – 2E+3	2
^{59}Fe	1 – 4E+3	35	^{140}La	1.11E+5	1
^{60}Co	0.01 – 9.8E+8	106	^{141}Ce	1E+2 – 3E+2	2
^{60}Cu	1.48E+3 – 7.4E+4	2	^{147}Pm	1E+2	1
^{61}Cu	1.48E+3 – 1.9E+4	2	^{152}Eu	1.2E-3 – 2.5E+2	55
^{62}Zn/^{62}Cu	1E+4	1	^{153}Eu	4E-2	1
^{63}Ni	3.34E+2 –	10	^{153}Gd	0.37 – 3.7E+4	71
^{64}Cu	6E+2 – 1.85E+5	9	^{153}Sm	10 – 1.11E+5	13
^{65}Zn	74 – 5E+2	2	^{166}Ho	1.11E+3 – 9E+5	3
^{67}Ga	1.62E+2 – 6E+4	195	^{169}Er	3.7E+2 – 7.4E+2	2
^{68}Ge/^{68}Ga	20 – 5E+3	31	^{171}Er	2.5E+2	2
^{75}Se	1 – 4E+3	32	^{186}Re	4.7E+2 – 1.2E+5	13
^{79}Kr	4E+5	1	^{188}W/^{188}Re	3E+3 – 4E+5	14
^{81}Rb/^{81m}Kr	1E+3 – 2E+5	3	^{192}Ir	6 – 5.55E+5	83
^{82}Br	1.11E+5	1	^{195}Au	2 – 5.44E+2	2
^{82}Sr/^{82}Rb	4E+3 – 1.6E+4	7	^{198}Au	1E+2 – 1.9E+4	15
^{83}Rb/^{84}Rb	1.8E+3	3	^{201}Tl	1.85E+2 – 5E+4	186
^{85}Kr	0.4 – 9.25E+6	3	^{204}Tl	0.37 – 1E+2	2
^{85}Sr	15 – 6E+4	13	^{210}Bi	0.37	1
^{86}Rb	33 – 4E+2	6	^{226}Ra	3.3E-2 – 4E+3	63
^{88}Y	0.4 – 4E+3	2	^{238}U	4E-3 - 2	4
^{89}Sr	2E+2 – 8E+3	82	^{238}Pu	3.7E+5	1
^{90}Sr	2E-4 – 3.7E+4	65	^{241}Am	5E-3 – 1.11E+5	50

4. Categorization of Sources

In the process of compiling the above list of radioisotopes used in medicine, the possibility to categorise isotopes into different risk levels based on their frequency of use, half-life, and number of licencees allowed to use that source became apparent. In order to work with a more manageable number, noble gases and radioisotopes with half-lives less than one day were eliminated from the list of 85 licenced sources. Note that short-lived radioisotopes produced from generators whose parent isotope has a half-life longer than one day remain on the list.

Two cuts were then made on the remaining 65 licenced radioisotopes. The first cut removed all sources with fewer than 20 licencees, thus eliminating isotopes that are not in widespread use in Canada. A list of these isotopes is given in Table 3. The second cut was made (to the original list) based on licenced activities, with all isotopes having less than 37 GBq (1 Ci) maximum allowed activity eliminated from the list. This list is provided in Table 4. It is important to point out that these reduced lists were created to simplify the problem of categorizing the risk of all isotopes licenced for medical use in Canada, and at this point it cannot be assumed that all sources on these lists are high risk for use in an RDD.

To that effect, the IAEA has performed a ranking of radioactive sources (in all applications) based on their potential to cause harm to human health [11]. Radioisotopes were ranked in one of five categories based on activity, mobility of the source, nature of the work, experience from reported accidents, and typical versus unique activities within an application. Several isotopes used in medicine were included in this ranking, and these radionuclides have been tabulated below (Table 5).

As mentioned, the sources were classified in five categories depending on their potential to cause immediate harmful health effects if the source was not safely managed or securely protected. Sources in category 1 are considered to be personally extremely dangerous and would likely cause permanent injury to a person in close proximity to it for more than a few minutes; category 2 sources are personally very dangerous and could cause permanent injury in a short time (minutes to hours); category 3 sources are personally dangerous, causing permanent injury following proximity over a few hours; category 4 sources are unlikely to be dangerous, but could temporarily injure someone close to it over many weeks; and category 5 sources are not considered dangerous.

While this ranking system seems to eliminate many of the medical isotopes due to their low risk, it is important to consider the potential of more than one of a particular source being obtained for illicit purposes. For that matter, despite the greater relevance of certain sources due to their availability and activity, it is possible that a multiplicity of less relevant sources could be included in an RDD. Also, it has been recognized that, while the use of lower risk non-fissile material in an RDD may not be ideal for creating mass casualties, the potential for disruption from such a device would be fundamentally disquieting [12].

Table 3. *Most frequently licenced isotopes in Canada (>20 licencees)*

ISOTOPE	HALF-LIFE	LICENCED QUANTITY		# OF LICENCEES	
		Sealed	***Open***	***Sealed***	***Open***
Am-241 (and Am/Be)	432.2 y	5 kBq – 40 GBq	111 GBq	49	1
Ba-133	10.52 y	4 kBq – 592 MBq	-	123	-
C-14	5730 y	925 kBq	2 MBq – 40 GBq	1	43
Co-57	271.79 d	150 kBq – 2 GBq	200 kBq – 9 GBq	195	153
Co-58	71.91 d	-	200 kBq – 3 GBq	-	88
Co-60	5.2714 y	10 kBq – 980 TBq	-	106	-
Cr-51	27.702 d	-	5 MBq – 7 GBq	-	123
Cs-137	30.07 y	40 kBq – 44 TBq	-	326	-
Eu-152	13.542 y	12 kBq – 100 MBq	250 MBq	52	2
Fe-59	44.503 d	-	1 MBq – 4 GBq	-	35
Ga-67	3.2612 d	-	162 MBq – 60 GBq	-	195
Gd-153	241.6 d	370 kBq - 37 GBq	100-400 MBq	69	2
Ge-68/Ga-68	270.82 d / 67.629 m	37 MBq - 1 GBq	370 MBq - 4 GBq	27	4
H-3	12.33 y	-	40 MBq – 3.7 TBq	-	29
I-125	59.408 d	400 kBq – 12 GBq	2 MBq – 11 GBq	25	124
I-131	8.0207 d	-	1 MBq – 80 GBq	-	320
In-111	2.8049 d	-	40 MBq – 50 GBq	-	171
Ir-192	73.831 d	6 MBq – 555 GBq	10 – 80 GBq	79	4
Mo-99/Tc-99m	65.94 h / 6.01 h	-	20 GBq – 5 TBq	-	220
Na-22	2.602 y	0.4 – 100 MBq	1 MBq – 4 GBq	14	11
P-32	14.262 d	0.1 – 74.4 GBq	40 MBq – 30 GBq	17	113
P-33	25.34 d	-	33 MBq – 4 GBq	-	21
Ra-226	1600 y	33 kBq – 4 GBq	-	63	-
S-35	87.51 d	-	10 MBq – 25 GBq	-	30
Se-75	119.779 d	-	1 MBq – 4 GBq	-	32
Sr-89	50.53 d	-	200 MBq – 8 GBq	-	82
Sr-90	28.78 y	200 Bq – 37 GBq	-	66	-
Tl-201	72.912 h	-	185 MBq – 50 GBq	-	186
Y-90	64.10 h	-	0.2 – 300 GBq	-	67

Table 4. *Highest activity licenced isotopes in Canada (>37 GBq)*

ISOTOPE	HALF-LIFE	LICENCED QUANTITY		# OF LICENCEES	
		Sealed	***Open***	***Sealed***	***Open***
Am-241 (and Am/Be)	432.2 y	5 kBq – 40 GBq	111 GBq	49	1
Br-82	35.30 h	-	111 GBq	-	1
C-14	5730 y	925 kBq	2 MBq – 40 GBq	1	43
Co-60	5.2714 y	10 kBq – 980 TBq	-	106	-
Cs-137	30.07 y	40 kBq – 44 TBq	-	326	-
Cu-60	5.2714 y	-	1.48 – 74 GBq	-	2
Ga-67	3.2612 d	-	162 MBq – 60 GBq	-	195
Gd-153	241.6 d	370 kBq - 37 GBq	100-400 MBq	69	2
H-3	12.33 y	-	40 MBq – 3.7 TBq	-	29
Ho-166	26.83 h	-	1.11 – 900 GBq	-	3
I-124	4.18 d	-	2 MBq – 100 GBq	-	5
I-131	8.0207 d	-	1 MBq – 80 GBq	-	320
In-111	2.8049 d	-	40 MBq – 50 GBq	-	171
Ir-192	73.831 d	6 MBq – 555 GBq	10 – 80 GBq	79	4
La-140	1.6781 d	-	111 GBq	-	1
Mo-99/Tc-99m	65.94 h / 6.01 h	-	20 GBq – 5 TBq	-	220
P-32	14.262 d	0.1 – 74.4 GBq	40 MBq – 30 GBq	17	113
Pu-238/Be	87.7 y	370 GBq	-	1	-
Re-186	90.64 h	-	0.74 – 120 GBq	-	13
Sm-153	46.27 h	-	10 MBq – 111 GBq	-	13
Sn-113 / In-113m	115.09 d / 1.658 h	-	4 – 200 GBq	-	7
Sr-85	64.84 d	60 GBq	15 MBq – 8 GBq	3	10
Sr-90	28.78 y	200 Bq – 37 GBq	-	66	-
Tl-201	72.912 h	-	185 MBq – 50 GBq	-	186
W-188 / Re-188	69.4 d / 16.98 h	-	10 – 74 GBq	-	14
Y-90	64.10 h	-	0.2 – 300 GBq	-	67

Table 5. *Ranking of isotopes used in medicine from the IAEA categorization of sources*

ISOTOPE	PRACTICE	QUANTITY IN USE (TYPICAL)	CATEGORY
Cs-137	Irradiators: blood/tissue	37 – 440 TBq (260 TBq)	1
	Teletherapy	19 – 56 TBq (19 TBq)	1
	Brachytherapy: high/medium dose-rate	110 – 300 GBq (110 GBq)	2
	Brachytherapy: low dose-rate	0.37 – 26 GBq (19 GBq)	4
Co-60	Irradiators: blood/tissue	56 – 110 TBq (89 TBq)	1
	Multi-beam teletherapy (gamma knife)	150 – 370 TBq (260 TBq)	1
	Teletherapy	37 – 560 TBq (150 TBq)	1
	Brachytherapy: high/medium dose-rate	190 – 740 GBq (370 GBq)	2
Ir-192	Brachytherapy: high/medium dose-rate	110 – 440 GBq (220 GBq)	2
	Brachytherapy: low dose-rate	0.74 – 28 GBq (19 GBq)	4
Pu-238	Pacemakers	110 – 300 GBq (110 GBq)	Not assigned (ranked 3)
Ra-226	Brachytherapy: low dose-rate	0.19 – 1.9 GBq (0.56 GBq)	4
I-125	Brachytherapy: low dose-rate	1.5 GBq	4
	Bone densitometry	1.5 – 30 GBq (19 GBq)	4
Au-198	Brachytherapy: low dose-rate	3 GBq	4
Cf-252	Brachytherapy: low dose-rate	3.1 GBq	4
Cd-109	Bone densitometry	0.74 GBq	4
	X-ray fluorescence analyzers	1.1 – 5.6 GBq (1.1 GBq)	5
Gd-153	Bone densitometry	0.74 – 56 GBq (37 GBq)	4
Am-241	Bone densitometry	1 – 10 GBq (5 GBq)	4
Mo-99	Diagnostic isotope generators	37 – 370 GBq (37 GBq)	Not assigned (ranked 4)
I-131	Medical unsealed	3.7 – 7.4 GBq (3.7 GBq)	Not assigned (ranked 4)
Fe-55	X-ray fluorescence analyzers	0.11 – 5 GBq (0.74 GBq)	5
Co-57	X-ray fluorescence analyzers	0.56 – 1.5 GBq (0.93 GBq)	5
Sr-90	Brachytherapy: low dose-rate – eye plaques and permanent implants	0.74 – 1.5 GBq (0.93 GBq)	5
Ru/Rh-106	Brachytherapy: low dose-rate – eye plaques and permanent implants	8.1 – 22 MBq (22 MBq)	5
Pd-103	Brachytherapy: low dose-rate – eye plaques and permanent implants	1.1 GBq	5
Ge-68	Positron emission tomography checking	37 – 370 MBq (110 MBq)	5
P-32	Medical unsealed	2.2 – 22 GBq (22 MBq)	Not assigned (ranked 5)

5. Discussion

Radioactive isotopes are used widely in medical applications around the world. These isotopes range from small activity brachytherapy implant sources to very large activity teletherapy sources. The goal of this study was to assess the availability and security of medical radioisotopes in Canada for inclusion into a probabilistic risk assessment tool for radiological dispersal devices for the CRTI project CRTI-02-0024RD.

In total, approximately 140 radioisotopes are used worldwide in medical applications for diagnostic, therapeutic, and preventative purposes. The number of radionuclides licenced in Canada for medical purposes are about 60% of this. In terms of isotopes of concern for use in an RDD, noble gases and short-lived sources were removed from the list, shrinking the number to 65 medical isotopes. The highest activity and most frequently used sources were then pulled out of this list, accounting for the most important medical radionuclides in Canada.

In terms of security of medical isotopes, national and international regulations require that higher activity (and thus higher risk) sources have more stringent security procedures in place to protect them. It may therefore be said that radioactive sources of greatest concern in a health care facility, such as large ^{60}Co and ^{137}Cs sources used in teletherapy and blood irradiator facilities, are likely to be the most secure. Smaller activity sources with less severe security requirements may still pose a threat since multiple sources may be combined together into a single device. This study has resulted in a compilation of medical radioisotopes used in Canada and discusses security of these sources in a typical health care facility. Ranking of these radionuclides has been performed on the basis of licenced source activity and overall number of licences for a particular isotope.

This study identifies a wide variety of radioactive sources used in medical procedures in Canada, which will be included in the CRTI probabilistic risk assessment project database. Information on the frequency of use and maximum licenced activity of these isotopes will be used to influence the probability assessment output from the PRA tool for a selected medical isotope. This information is representative of the radioactive licences in Canada in early 2004, and thus should be updated periodically to ensure the information remains current. Similar data gathering efforts should be performed for radioisotopes used in other applications.

6. References

1. Cameron, G. *The likelihood of nuclear terrorism*. The Journal of Conflict Studies (1998).

2. Lubenau, JO, and Strom, DJ. *Safety and security of radiation sources in the aftermath of 11 September 2001*. Health Physics, **83**:2 (2002).

3. Haslip D.S. *Project Charter (CRTI-02-0024RD: Probabilistic Risk Assessment for Radiological Dispersal Devices) to the Memorandum of Understanding concerning the Chemical, Biological, Radiological or Nuclear Research and Technology Initiative (CRTI)*, DRDC Ottawa, 2 June 2003.

4. INTERNATIONAL ATOMIC ENERGY AGENCY. *Response to events involving the inadvertent movement or illicit trafficking of radioactive materials*. IAEA-TECDOC-1313, Vienna (2002).

5. INTERNATIONAL ATOMIC ENERGY AGENCY. *Nuclear technology review. Annex VIII: The socio-economics of nuclear applications: a perspective*. Vienna (2004). pp 85 – 94.

6. National Council on Radiation Protection and Measurements (NCRP). *Sources and magnitude of occupational and public exposures from nuclear medicine procedures*. NCRP Report No. 124, March 1996.

7. Groth, S. *Nuclear applications in health care – lasting benefits*. IAEA Bulletin, 42/1/2000, Vienna (2000).

8. UNITED NATIONS. *Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000 Report to the General Assembly, with Scientific Annexes*. No. E.00.IX.3. United Nations, New York (2000).

9. INTERNATIONAL ATOMIC ENERGY AGENCY. *Security of radioactive sources – Interim guidance for comment*. IAEA-TECDOC-1355, Vienna (2003).

10. CNSC Database on radiation licencees in Canada. Provided by CNSC, March 2004.

11. INTERNATIONAL ATOMIC ENERGY AGENCY. *Categorization of radioactive sources – Revision of IAEA-TECHDOC-1191, Categorization of radiation sources*. IAEA-TECHDOC-1344, Vienna (2003).

12. Lesser, IO, Hoffman, B, Arquilla, J, Ronfeldt, DF, Zanini, M, Jenkins, BM. *Countering the new terrorism.* Santa Monica, CA: The Rand Corporation; MR-989-AF (1999).

Annex A

The following table (Table 6) describes the application, typical administered activity, and other relevant information for the most common and highest licenced activity medical sources.

Table 6. *Properties and uses of common medical radioisotopes in Canada*

ISOTOPE	HALF-LIFE	APPLICATIONS	FORM / MODE OF ADMINISTRATION	TYPICAL ADMINISTERED ACTIVITY	QUANTITY TYPICALLY STORED
Am-241 (and Am/Be)	432.2 y	1. Diagnostic: Radiation source for bone mineral analyzer (for osteoporosis). Heart imaging? 2. Therapeutic: Antineoplastic	Encapsulated source. 1. External irradiation 2. Intracavitary irradiation	370 MBq (10 mCi)	1 - 10 GBq (27 - 270 mCi)
Ba-133	10.52 y	Dose calibrators	Dose calibrator reference vial	4 kBq – 9.25 MBq (0.1 – 250 μCi)	Up to 592 MBq (16 mCi)
Br-82	35.30 h	Diagnostic: tracer studies: 1. imaging adrenal, ovary or prostate tissue 2. study of electrolyte balance 3. In metabolic studies and studies of estrogen receptor content	1. Ammonium bromide, orally 2. Cuprous bromide, i.v. 3. i.v.	1. 0.6 μCi/kg 2,3. varying amounts	Up to 111 GBq
C-14	5730 y	1. Radiolabeling for detection of tumors (breast, et al.) 2. Autoradiography	1. Injection 2. Inhalation, oral capsules	37 kBq (1 μCi) for both	Up to 40 GBq (1.1 Ci)
Co-57	271.79 d	1. Diagnostic: In Schilling test for defects of intestinal vitamin B12 absorption 2. Gamma camera calibration; radiotracer in research; source for X-ray fluorescence spectroscopy; Organ size estimation; in-vitro diagnostic kits	1. Radioactive vitamin B12 taken orally 2. Dose calibrator reference sources	1. 37kBq (1μCi)	2. 0.56 – 1.5 GBq (15 – 40 mCi) (max activity used per month: 1. 0.5 mCi)
Co-58	71.91 d	Diagnostic: In Schilling test for defects of intestinal vitamin B12 absorption	Radioactive vitamin B12 taken orally	37kBq (1μCi)	Up to 3 GBq (81 mCi)
Co-60	5.2714 y	1. Therapeutic: Antineoplastic (teletherapy source, intracavitary or interstitial radiation source) 2. Disinfect surgical equipment and medicines 3. Diagnostic: In Schilling test for defects of intestinal vitamin B12 absorption	1 & 2. Metallic cobalt used externally, intracavitarily or interstiltially 3. Radioactive vitamin B12 taken orally	1 & 2. N/A 3. 37kBq (1μCi)	1 & 2. Up to 560 TBq (15 kCi)
Cr-51	27.702 d	1. Diagnostic: Determination of serum protein loss into the gastrointestinal tract. 2. Determn of glomerular filtration rate 3. Placenta localization; gastrointestinal protein loss 4. Determn of red cell volume or mass; red cell survival time; evaluation of blood loss; spleen imaging; placenta localization	1. Chromic chloride 2. Chromium disodium edetate 3. Labeled human serum albumin 4. Sodium chromate labeled red blood cells i.v. administration for all	4. 5.6 MBq (0.15 mCi)	Up to 7 GBq (200 mCi) (max activity used per month: 4. 5 mCi)

Cs-137	30.07 y	Therapeutic: Antineoplastic (teletherapy source, intracavitary or interstitial radiation source)	Cesium chloride or cesium sulphate (encased in needles or applicator cells) via external, intercavitary, or interstitial irradiation	N/A	Up to 440 TBq (12 kCi)
Cu-60	5.2714 y	Laboratory studies	Open source	N/A	Up to 74 GBq (2 Ci)
Eu-152	13.542 y	1. Sterilization of medical supplies 2. Calibration source 3. Laboratory studies	1. sealed source 2. Dose calibration reference source	2. 3.7 –370 kBq (0.1 – 10 μCi)	Up to 250 MBq (7 mCi)
Fe-59	44.503 d	1. Diagnostic Ferrokinetics 2. D: Red cell maturation studies	1. Ferric chloride, ferrous citrate, ferrous sulphate 2. Labelled red blood cells i.v. administration for both		Up to 4 GBq (110 mCi) (Max activity per month: 1. 3 mCi)
Ga-67	3.2612 d	Diagnostic: Detection of neoplastic and inflammatory lesions; tumour seeking agent	i.v. administration of gallium citrate	185 MBq (5 mCi)	Max activity used per month 1.4 Ci
Gd-153	241.6 d	Diagnostic: Radiation source for bone mineral analyzer (for osteoporosis), SPECT imaging	Sealed source for external irradiation	N/A	0.74 – 56 GBq (0.02 – 1.5 mCi)
Ge-68/Ga-68	270.82 d / 67.629 m	PET imaging	i.v.	37 – 370 MBq (1 – 10 mCi)	Up to 5 GBq (135 mCi)
H-3	12.33 y	Used in medical research laboratories to tag DNA for in vitro autoradiography	Tritium gas or tritiated water. H-3 can be labelled to MANY different molecules. Not administered to patients. Labelled to DNA in a blood sample.	N/A	Varies
Ho-166	26.83 h	Therapy isotope for development of liver cancer treatment by injection of PLA microspheres. Used in clinical trial in Europe of new blood cancer treatment.	Ho-166 labelled microspheres	Up to 150 GBq (4 Ci)	Up to 900 GBq (25 Ci)
I-124	4.18 d	Radiotracer used to create images of human thyroid, PET imaging.	i.v.	37 μCi	Up to 100 GBq (2.7 Ci)
I-125	59.408 d	1. Therapeutic: low dose rate brachytherapy 2. Diagnostic: Radiation source for bone mineral analyzer 3. D: Pancreatic function; intestinal fat absorption 4. D: Localization of deep vein thrombosis; study of fibrinogen metabolism; In vitro determn of fibrinolytic enzymes 5. D: Determn of blood or plasma volume; circulation time; cardiac output 6. D: Diagnostic: Metabolic study of endogenous thyroxine. In vitro determination of thyroid function 7. D: In vitro determn of thyroid function 8. D: Protein-loss enteropathy 9. D: Liver function in hepatic excretion studies 10. D: Thyroid function studies; thyroid imaging	1 & 2. Sealed source, external irradiation 3. Iodinated fats or fatty acids, orally 4. Iodinated fibrinogen, i.v. or *in vitro* 5. Iodinated human serum albumin (IHSA) 6. Iodinated levothyroxine, i.v. or in vitro 7. Iodinated liothyronine, in vitro 8. Iodinated povidone, i.v. 9. Iodinated rose Bengal, i.v. 10. Sodium iodide, orally or i.v.	5. 0.74 MBq (0.02 mCi)	1 & 2. 1.5 – 30 GBq (40 – 800 mCi)

I-131	8.0207 d	1. Diagnostic: Brain scan 2. D: Adrenomedullary imaging and tumor detection Therapeutic: Antineoplastic (radiation source) in treatment of neuroendocrine tumours 3. D: Pancreatic function; intestinal fat absorption 4. D: In vitro determn of fibrinolytic enzymes 5. D: Plasma volume determn; peripheral vascular flow; cardiac output; circulation time; cerebral vascular flow; brain scan; placenta localization; cistemography 6. D: Pulmonary perfusion imaging 7. D: Hepatic blood pool imaging 8. D: Metabolic study of endogenous thyroxine; In vitro determn of thyroid function 9. D: In vitro determn of thyroid function 10. D: Protein-loss enteropathy 11. D: Liver function in hepatic excretion studies 12. Therapeutic: Antineoplastic (radiation source) in treatment of non-Hodgkin's lymphoma 13. D: Determn of renal function, renal blood flow, urinary tract obstruction; renal imaging 14. D: Thyroid function studies; thyroid imaging Therapeutic: Hyperthyroidism; neoplastic (radiation source) in treatment of thyroid cancer	1. Diiodofluorescein, i.v. 2. Iobenguane (MIBG), i.v. 3. Iodinated fats and fatty acids, e.g. oleic acid, triolein, orally 4. Iodinated fibrinogen, in vitro 5. Iodinated human serum albumin (IHSA), i.v. or intrathecal 6. Iodinated human serum albumin (macroaggregated), i.v. 7. Iodinated human serum albumin (microaggregated), i.v. 8. Iodinated levothyroxine, i.v., in vitro 9. Iodinated liothyronine, in vitro 10. Iodinated povidone, i.v. 11. Iodinated rose Bengal, i.v. 12. Iodinated tositumomab, i.v. 13. Iodohippurate sodium, i.v. 14. Sodium iodide, orally or i.v.	2. 0.74 MBq (0.02 mCi) 13. 0.74 MBq (0.02 mCi) 14. 3700 MBq (100 mCi)	3.7 - 7.4 GBq (max activity used per month: 2. 10 mCi 11. 5 mCi 13. 5 mCi 14. 500 mCi)
In-111	2.8049 d	1. Diagnostic: Tumor detection 2. D: Tumor detection for prostate cancer 3. D: Hematopoietic bone marrow imaging; tumour detection 4. D: Detection of abscesses, infections and inflammation 5. D: Detection of deep vein thrombosis; cardiac thrombosis; renal transplant rejection 6. D: Detection of gastrointestinal bleeding 7. D: Gastric emptying studies; cardiac output; renal scintigraphy; cisternography 8. D: Neuroendocrine tumor detection 9. D: Tumor detection	1. Indium bleomycin, i.v. 2. Indium capromab pendetide, i.v. 3. Indium chloride, i.v. 4. Indium oxyquinoline (oxine) labeled leukocytes, i.v. 5. Indium oxyquinoline (oxine) labeled platelets, i.v. 6. Indium oxyquinoline (oxine) labeled red blood cells, i.v. 7. Indium pentetate (DTPA), Orally; i.v.; Intrathecal, intracisternal or intraventricular 8. Indium pentetreotide, i.v. 9. Indium satumomab pendetide, i.v.	4. 19 MBq (0.50 mCi) 7. 0.5 mCi 8. 222 MBq (6 mCi)	Max activity used per month: 100 mCi

Ir-192	73.831 d	Antineoplastic (interstitial radiation source); cancers of the prostate, brain, breast, cervix, lung (high dose rate brachytherapy using remote loaded sources); Head and neck, tongue and mouth cancer (low dose rate brachytherapy using iridio-platinum wires and needles). Preventive therapy for e.g. restenosis prevention in blood vessels using remote loaded sources.	Seed encased in nylon ribbon; Ir wires – given via interstitial irradiation	N/A	HDR: 110 - 440 GBq (3 - 12 Ci) LDR: 0.74 - 28 GBq (20 - 750 mCi)
La-140	1.6781 d	GI studies	Lanthanum citrate, orally	370 – 740 kBq (10 – 20 μCi)	111 GBq (3 Ci)

Mo-99/Tc-99m	65.94 h / 6.01 h	1. Diagnostic: Brain imaging. Cerebral angiography; thyroid imaging; salivary gland imaging; placenta localization; blood pool imaging; gastric mucosa imaging; cardiac function studies; renal blood flow studies; Urinary bladder imaging; Nasolacrimal drainage system imaging 2. Determn of red blood cell volume, short-term survival studies; In vitro compatibility studies 3. Blood pool imaging; cardiovascular studies; placenta localization; determn of blood or plasma volumes 4. Pulmonary perfusion imaging 5. Liver imaging 6. Acute venous thrombosis imaging 7. Tumor detection for colorectal cancer 8, 9. Brain imaging 10. Tumor detection for lung cancer 11. Hepatobiliary imaging 12, 18, 20. Bone imaging 13. Cerebral perfusion imaging 14. Brain imaging; renal imaging; assess renal and brain perfusion 15. Determn of red cell volume; short-term red cell survival studies 16. Hepatobiliary imaging 17. Hepatobiliary imaging 19, 25. Renal imaging 21. Brain imaging; renal imaging; assess renal and brain perfusion; estimate glomerular filtration rate Lung ventilation studies 22, 23. Bone imaging; myocardial imaging; blood pool imaging; detection of gastrointestinal bleeding 24, 28, 29. Myocardial perfusion imaging 26. Detection of infections and inflammation 27. Liver, spleen and bone marrow imaging, Esophageal transit studies; gastroesophageal reflux scintigraphy; determn of pulmonary aspiration of gastric contents; detection of intrapulmonary and lower gastrointestinal bleeding; lung ventilation imaging	1. Sodium pertechnetate, Orally, i.v., urethral catheterization or direct instillation 2. Sodium pertechnetate labeled red blood cells, i.v., in vitro 3. Tc-albumin, i.v. 4. Tc-albumin (aggregated), i.v. 5. Tc-albumin (microaggregated), i.v. 6. Tc-apcitide, i.v. 7. Tc-arcitumomab, i.v. 8. Tc-bicisate, i.v. 9. Tc-butedronate (DPD), i.v. 10. Tc-depreotide, i.v. 11. Tc-disofenin (DISIDA), i.v. 12. Tc-etidronate (EHDP), i.v. 13. Tc-exametazine (HMPAO), i.v. 14. Tc-gluceptate, i.v. 15. Tc-labeled red blood cells, i.v. 16. Tc-lidofenin (HIDA), i.v. 17. Tc-mebrofenin, i.v. 18. Tc-medronate (MDP), i.v. 19. Tc-mertiatide (MAG3), i.v. 20. Tc-oxidronate (HDP), i.v. 21. Tc-pentetate (DTPA), i.v., Inhalation 22. Tc-polyphosphates, i.v. 23. Tc-pyrophosphate, i.v. 24. Tc-sestamibi (HEXAMIBI), i.v. 25. Tc-succimer, i.v. 26. Tc-sulesomab, i.v. 27. Tc-sulfur colloid, i.v., orally, inhalation 28. Tc-teboroxime, i.v. 29. Tc-tetrofosmin, i.v.	1. 370 MBq (10 mCi) 4. 148 MBq (4 mCi) 6. 740 MBq (20 mCi) 8. 740 MBq (20 mCi) 10. 740 MBq (20 mCi) 11. 185 MBq (5 mCi) 13. 740 MBq (20 mCi) 15. 740 MBq (20 mCi) 18. 740 MBq (20 mCi) 19. 370 MBq (10 mCi) 21. 370 MBq (10 mCi) 23. 555 MBq (15 mCi) 24. 740 MBq (20 mCi) 25. 185 MBq (5 mCi) 29. 740 MBq (20 mCi)	37 - 370 GBq (1 - 10 Ci) Comes from decay of Mo-99. Stored in a 99Mo/99mTc generator that is "milked" for each scan. Generator is refilled every week. Max activity used per month: 40 Ci
Na-22	2.602 y	Diagnostic: Determn of sodium space and total exchangeable sodium	Sodium chloride via i.v.	370 kBq (10 μCi)	Up to 4 GBq (11 mCi)

P-32	14.262 d	1. Diagnostic: Blood volume determn 2. Diagnostic: Study of peripheral vascular disease; localization of ocular, brain and skin tumors; study of breast carcinomas Therapeutic: Polycythemia vera; chronic myelocytic leukemia; chronic lymphocytic leukemia; skeletal metastases; antineoplastic (radiation source) 3. Therapeutic: Antineoplastic (radiation source) in treatment of peritoneal or pleural effusions caused by metastatic disease	1. Labeled red blood cells, i.v. 2. Sodium phosphate, orally, i.v., Intrapleural or intraperitoneal 3. Chromic phosphate, Intrapleural or intraperitoneal	2. 148 MBq (4 mCi) 3. 6 – 20 mCi	2. 2.2 – 22 GBq (60 – 600 mCi) (max activity used per month: 30 mCi)
P-33	25.34 d	1. Leukemia treatment, bone disease diagnosis/treatment, radiolabeling, and treatment of blocked arteries (i.e., arteriosclerosis and restenosis) 2. laboratory studies	1. P-32 labelled DNA, RNA, oglionuclides, etc. via i.v. 2. in vitro	1. Small quantities 2. N/A	Up to 4 GBq (11 mCi)
Pu-238/Be	87.7 y	Pacemaker (no Pu-236 contaminants).	Sealed source	N/A	370 GBq (10 Ci)
Ra-226	1600 y	Therapeutic: Antineoplastic (radiation source) in treatment of malignancies such as cancer of uterine cervix and fundus, oral pharynx, urinary bladder, skin and metastatic cancer of lymph nodes	Radium bromide, interstitial irradiation	N/A	0.19 - 1.9 GBq (5 - 50 mCi)
Re-186	90.64 h	Used for pain relief in bone cancer. Beta emitter with weak gamma for imaging.	Re-186-HEDP, i.v.	Up to 555 MBq (15 mCi)	Up to 120 GBq (3 Ci)
S-35	87.51 d	Diagnostic: Determn of extracellular fluid volume	Sodium sulphate, i.v.	Up to 370 MBq (10 mCi)	25 GBq (700 mCi)
Se-75	119.779 d	Diagnostic: Imaging of pancreas and parathyroid glands	Selenomethionine, i.v.	Up to 3.7MBq (100 μCi)	Up to 4 GBq (11 mCi)
Sm-153	46.27 h	Therapeutic: Antineoplastic (radiation source) in treatment of bone cancer; Pain relief of secondary cancers in bone; prostate and breast cancer treatment	Sm-lexidronam (EDTMP), i.v.	2590 MBq (70 mCi)	Up to 111 GBq (3 Ci)
Sn-113 / In-113m	115.09 d / 1.658 h	1. Diagnostic: liver and spleen imaging 2. Diagnostic: Pulmonary perfusion imaging; cardiac output 3. Diagnostic: Determination of blood volume 4. Diagnostic: Brain scan; renal function studies. 5. Diagnostic: Static cardiovascular blood pool imaging; hepatic and placenta blood pool imaging; placenta localisation	1. Indium colloid 2. Indium Fe(OH)3 3. Indium labeled rad blood cells 4. Indium pentetate (DTPA) 5. Indium transferring i.v. administration for all	0.5 mCi	Up to 200 GBq (5.4 Ci)
Sr-85	64.84 d	Diagnostic: Bone imaging	Strontium chloride, strontium nitrate i.v. administration	(5 – 100 μCi)	Up to 60 GBq (1.6 Ci)
Sr-89	50.53 d	Prostate cancer pain relief; beta emitter	Strontium chloride	148 MBq (4 mCi)	Max activity per month: 40 mCi

Sr-90	28.78 y	Therapeutic: Treatment of benign conditions of eye such as pterygia, traumatic corneal ulceration, corneal scars, vernal conjunctivitis, hemangioma of eyelid, vascularization of cornea and in preparation for a corneal transplant	Beta ray applicator, external irradiation	N/A	0.74 - 1.5 GBq (20 - 40 mCi)
Tl-201	72.912 h	Diagnostic: Myocardial perfusion imaging; localization of sites of parathyroid hyperactivity	Thallous chloride, i.v.	74 MBq (2 mCi)	Max activity used per month 700 mCi
W-188 / Re-188	69.4 d / 16.98 h	Cancer treatment, monoclonal antibodies	i.v.	Up to 14.8 GBq (0.4 Ci)	Up to 74 GBq (2 Ci)
Y-90	64.10 h	Therapeutic: Antineoplastic (radiation source) in treatment of non-Hodgkin's lymphoma; Internal (intra-arterial) radiotherapy of liver cancer, monoclonal antibodies, Hodgkins disease, and hepatoma, cellular dosimetry, treating rheumatoid arthritis, treating breast cancer, treatment of gastrointestinal adenocarcinomas	Y-Ibritumomab tiuxetan, Y-90 citrate, i.v.	Up to 370 MBq (10 mCi)	Up to 300 GBq (8 Ci)

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An assessment of the availability of radioactive material used for medical applications in Canada has been performed as part of the CBRN Research and Technology Initiative (CRTI) Project CRTI-02-0024RD (Probabilistic Risk Assessment Tool for Radiological Dispersal Devices). A general list of medical radioisotopes used worldwide was compiled via literature searches and Internet investigations. This list was then compared to all isotopes licenced to health care facilities in Canada. Noble gases, short-lived isotopes, and radioisotopes not licenced for medical applications in Canada were eliminated. The remaining sources were then analysed for frequency of use and maximum licenced activity to assess which materials would be of highest concern in relation to radiological terrorism. A detailed description of the application, typical administered activity, and other relevant information for these most common and highest licenced activity medical sources was assembled to feed directly into the risk assessment database. A general discussion of security in healthcare facilities is also given. Due to the constant advances made in medicine, the information relating to licenced isotopes is dynamic and thus requires updating to ensure the database is kept up to date.

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Medical isotopes, radioactive source security, radiological dispersal device, risk assessment, terrorism

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